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Abstract

Nairobi County is faced with acute water scarcity and streets are often flooded during heavy downpour. The aims of this research were to assess the adoption of roof catchment rainwater harvesting and major water sources in Nairobi County. Samples were picked from Kabete Dagoretti, Wilson, Moi Airbase and J.K.I.A meteorological weather stations. Assessment was done in Maisonette and multi- story residential buildings, institutions and industries followed by a descriptive analysis. The outcome of the study revealed that typical sources of water were City council piped water, borehole and roof catchment rainwater harvesting. Most buildings solely depended on City Council piped water; industries 76%, institutions 48%, maisonettes 56% and multi-story buildings 50%. There was no building depending solely on roof catchment rainwater harvesting. The ones who harvested rainwater did it as supplement to City Council piped water and/or boreholes. Institutions are leading in rainwater harvesting 44% followed by maisonettes 20%, multi-story buildings 6% and industries have least adopted rainwater harvesting 4%. The overall adoption of roof catchment rainwater harvesting is 16%. Most residents, 79.4% were not harvesting rainwater because rainwater harvesting systems were not included in the initial planning or architectural design of buildings. But 84.6% felt that roof catchment rainwater harvesting should be practiced by every building. Roof catchment rainwater harvesting can solve problems of water scarcity in Nairobi County. Every building should harvest rainwater and store it in appropriate storage capacity that depends on water demand in the building and rainfall supply.

1.0 INTRODUCTION

The demand of water in urban areas largely exceeds supply. Urban areas depend on water from distant sources conveyed by large infrastructures, encumbered by leakage and vandalism (Jeremy. 2012). Total non-potable water uses are 78% for domestic building and 86% for office building (Noah Garrison *et al*., 2011); this indicates a large percentage of non-potable water than potable water needs. The quality of rainwater from roof tops has been considered suitable for non-potable purposes without subject to any treatment (Gakungu, 2013; Mendes *et al*., 2010). However, this resource is disposed as storm water using centralized drainage systems. This quickly turns rainwater from a valuable resource into a menace in form of flooding, erosion and toxic loading on rivers and treatment plants (Gabe et al., 2012; Jackson, 2001).

Rainwater harvesting is defined as the practice of collecting water from surfaces on which rain falls and storage of this water for later use (Julius *et al*., 2013). Roof catchment rainwater harvesting system basically

consists of the roof – top as the catchment area, gutters for collecting water and storage tanks **(**Julius et al, 2013**)**. The size of the tank depends on available roof–top area, rainfall and user's water consumption (International Relief Development, 2013; Jothiprakash et al, 2009). The volume of rainwater from roof catchments might meet water demand of occupants of that building, but this resource is disposed as storm water. Some City residents consume less than 40 Litres person per day (lpcd). World health organization suggests that 40 lpcd is fit for a simple life, but that is beyond reach of many consumers in Nairobi. (Ledant.M *et al.*, 2010; Moraa. *et a*l., 2012)

Water supply deficit for Nairobi City is currently 170,000 m^3/day or 23% of the current demand. This deficit will rise to 280,000 m^3/day and 970,000 m^3/day by 2017 and 2035, respectively if water supply alternatives are not implemented (Athi Water Services Board, 2012). Roof catchment rainwater harvesting has been ignored which would be a solution to water crisis; few residents have adopted roof catchment rainwater harvesting.

The study was conducted in Nairobi City County which has an area of 684 km^2. It is the Capital City of Kenya with an altitude of 1798 m and average annual rainfall of about 900 mm, but the actual amount in any one year may vary from 500 mm to 1500 mm. There are two rainy seasons, from mid-March to the end of May (Long Rains), and from mid-October to mid-December (Short Rains).

Rainfall Thiessen polygons were constructed using ArcGIS Version 9.2 software as shown in figure 1. The Thiessens classified the County into five sections based on meteorological stations: Kabete, JKIA, Moi Airbase, Wilson and Dagoretti. A classification into Multi-story residential buildings, Maisonettes residential buildings institutions and industries was done. Then, a random sampling method was used to select 10 samples of maisonettes and multi-story buildings in each polygon, five institutions in each polygon and twenty five industries from industrial area which predominately fall in J.K.I.A meteorological polygon. A total of one hundred and fifty samples were obtained. A Germin, Global positioning system (GPS) was used to locate sample positions.

MATERIALS AND METHODS

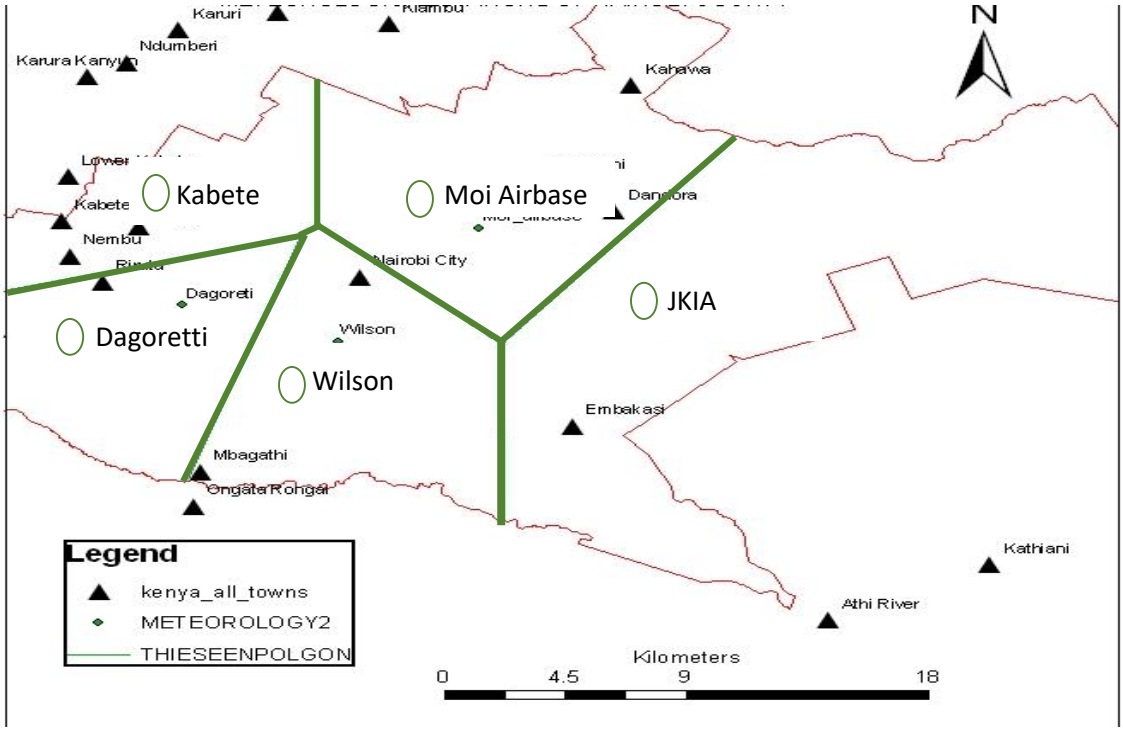

Figure 1: Meteorological Thiessen Polygons for Nairobi County

RESULTS AND DISCUSSIONS

Results and discussions are presented as per the four classes of buildings assessed; Institutions, industries, Maisonette and Multi- Story residential buildings.

Institutions

These were mainly schools and churches. Roofing materials were corrugated iron sheets that were 72%, followed by clay tiles 24% and others were 4%. Sources of water varied, about 48% relied on City council piped water and only 44% harvested rain water from roof tops.

The uses of water was mostly for non-portable purposes such as cleaning floors, flushing toilets, watering plants and recharging swimming pools; rarely was it used for food preparation or drinking. Majority of institution considered the source of water as reliable. In case of shortages they used stored water from reservoirs, skipped regular chores such as cleaning, bought water from nearby boreholes, tankers or handcarts.

The ones that harvested rainwater from roof catchments, 82% used above ground plastic tanks for storage while, 18% used underground concrete tanks. The size of these storage tanks were in the range of 20000, 24000, 30000, 40000, 48000 and 100000 litres. The tanks would serve the users for one week, one month or two months. The uses of rainwater from roof catchment was mainly for cleaning floors, flushing toilets, watering plants, washing cloths and bathing. A 66% were satisfied with their rainwater harvesting systems, 34% were not satisfied. The source of money for financing rainwater harvesting systems was from own money and/or donations. There were no reported diseases associated with water usage in any of the institutions. According to Utsau *et al* (2014), rainwater harvesting from roof catchments met water demand for students in the Campus. Adoption of rainwater harvesting is high in institutions than other classes of buildings assessed. This has been facilitated by funds from donations and Government.

Industries

The industries studied were metal products manufacturing, Agro chemical and food processing, warehouses/dispatch and transport. The type of roofing materials were corrugated iron sheets (84%), clay tiles (12%) and others were 4%. Industries largely (76%) depended on city council piped water and only 4% harvested rainwater, despite having a potential of meeting their water demand (mean of 215%) from roof top rain catchment. Non potable indoor and outdoor water uses would be 86% and above for industries (Noah. G, 2011) and rainwater quality from roof tops is suitable for these purposes; unfortunately the resource is disposed as storm water. It would be prudent if industries harvest rain water in order to allow some percentage of City council piped water (potable water) to residential (domestic) buildings because according to Noah *et al* (2011) residential buildings need more potable water than industries (21.7% and 14%, respectively).

Maisonettes Residential buildings

The type of roofing materials was majorly clay tiles (72%), corrugated iron sheets (12%), concrete tiles (10%) and others were 6%. The source of water differed with City council piped water leading (56%) and only 20% harvested rainwater. However, 72% indicated that water sources were reliable, while 28 % said that it was not reliable at all. In times of shortages, 55% bought water from vendors such as water tankers or handcarts while 36% used water from their own reservoirs that had been stored for water shortage sessions. The others either recycled or minimized usage. A number of residents, (30%) used water for irrigating kitchen gardens, green houses or flowers.

The ones who harvested rainwater (20%) from roof catchments, 44% used above ground plastic storage tanks while 56% used underground concrete tanks. The capacities were; 1000, 1200, 5000, 10000, 20000 and 24000 litres. The uses of rainwater from roof catchment was mainly for laundry, flushing toilets, irrigating plants (non-potable uses) and some used it for all domestic chores. A 77% were satisfied with their rainwater harvesting system, the others were not. Majority of them (88%) used their own money, while 12% used loans to finance storage reservoirs. There were no diseases associated with water usage in any of Maisonette buildings.

Multi-story residential buildings

The type of roofing materials was corrugated iron sheets (50%), clay tiles (36%), Aluminum sheets (6%), concrete tiles (2%) and others 6%. Sources of water varied with City council piped water leading (50%) and only 6% harvested rainwater.

Most buildings in this category indicated that water sources were not reliable at all (46%), a higher rate than any type of building highlighted. On the other hand, 54% had a reliable water source throughout the year. Majority of those who experienced water shortages bought water from water tankers or handcart vendors (60%), the others used water from their reservoirs. The rate of rainwater harvesting from roof catchments were very low, (6%). The kind of storage reservoir used was underground concrete tank of capacities 1000, 1500 and 5000 litres, having been financed by owner's money. Water from these reservoirs would serve residents within a week. The harvesting systems were satisfactory and there were no

diseases associated with rainwater usage although, some used it for all domestic chores.

The overall adoption of roof catchment rainwater harvesting in Nairobi County was 16 %. There was no building completely depending on roof catchment rainwater harvesting. In roof catchment rainwater harvesting, water demand in the building, roof surface area and rainfall supply should be considered in determining storage capacity. But the buildings that harvested rainwater used storage capacities that were far less than what was required. This was due to roof catchment rainwater harvesting being an afterthought and affordability of storage facilities by owners rather than an initial appropriate architectural in cooperation. The residents suggested rainwater harvesting in Nairobi City County in order to supplement borehole and surface water supplies, reduce cost of operations such as energy used for pumping, reduce flooding, mitigate water theft along pipelines and reduce competition for surface and underground water resources. Table 1 shows different sources of water per class of building where f is frequency.

Table 1: Sources of water for different classes of buildings

	Source of water	Institutions		Industry		Maisonettes		Multi-story	
		f	%	f	%	f	%	f	%
1	City council	12	**48**	19	**76**	28	**56**	25	**50**
2	Private borehole, city council, and roof top rain catchment	3	**12**	0	**0**	1	**2**	0	**0**
3	City council and Roof top rain catchment	8	**32**	1	**4**	8	**16**	3	**6**
4	Private borehole and city council	2	**8**	5	**20**	9	**18**	15	**30**
5	Private borehole and roof top rain catchment	0	**0**	0	**0**	1	**2**	0	**0**
6	Private borehole only	0	**0**	0	**0**	3	**6**	7	**14**
	Total	25	**100**	25	**100**	50	**100**	50	**100**

(f: frequency) (%: Percentage)

Perceptions and challenges facing roof catchment rainwater harvesting in Nairobi County

Assessment of perception, and challenges of roof –top rainwater harvesting in Nairobi County was conducted where responses to the questions were: 1 – strongly disagree 2 – Disagree 3 – Neutral 4 - agree and 5 – Strongly agree. The results are as shown in table 2 in terms of frequency (F), Maximum, Minimum, Mean and Standard deviation

Table 2: Perception and challenges facing roof catchment rainwater harvesting in Nairobi County

	Reasons for not harvesting rainwater	F	Max	Min	Mean	Std dev
i	No storage tank	122	5	1	3.24	1.28
ii	Piped water is reliable	124	4	1	1.94	0.877
iii	There is no space to install a tank	121	4	1	1.83	0.69
iv	It is costly to install a rainwater harvesting system	123	5	1	1.97	0.71
v	The City council does not allow rainwater harvesting	121	5	1	2.21	0.92
vi	Rainwater harvesting systems were not included in the initial planning or architectural design	120	5	1	3.97	1.04
The following might be causes of flooding in Nairobi County						
i	No drainage system	92	5	1	3.1	1.11
ii	The drainage system is there but blocks during heavy rains	128	5	1	4.0	0.95

Perception of Roof top Rainwater Harvesting in Nairobi						
i	Rainwater harvesting in Nairobi will increase water quantity and sanitation	142	5	1	4.23	0.76
ii	Rainwater harvesting in Nairobi will reduce flooding and the associated damages	140	5	1	4.13	0.77
iii	Rain water quality is suitable for industrial and domestic consumption	138	5	1	4.17	0.78
iv	Rain water harvesting will reduce the cost of pumping water from NWSC, constructing and maintaining drainage systems	142	5	1	4.15	0.79

Most residents (79.4) felt that they were not harvesting rainwater because rainwater harvesting systems were not included in the initial planning or architectural design of the building. However, 84% felt that rainwater harvesting in Nairobi would increase water quantity and sanitation, it would also reduce flooding and associated damages 82.6% and that rainwater quality is suitable for some domestic and industrial uses, 83.4%. Most buildings (77%) were completely guttered with collection pipes and 98% had an approximate space of 4 m^2.

Conclusions

Only 16% harvest rainwater from roof catchments and institutions are leading followed by maisonettes buildings, Multi-story residential buildings and industries have least adopted roof catchments rainwater harvesting. Most residents are not harvesting rainwater from roof catchments because they do not have storage facilities. Moreover, rainwater harvesting facilities are not included in the initial designs and construction of buildings. Those who harvest water from roof catchments, they use that water for non-potable purposes and they have not experienced diseases associated with rainwater usage.

Urban water management should shift from depending on centralized systems alone and encourage decentralized systems such as domestic rainwater harvesting. This will increase water quantity and sanitation. Rainwater harvesting should be included in building designs. Water harvesting techniques in the design process and an offer of storage tanks at subsidized prices will greatly lead to achievement of domestic rainwater harvesting to every building in urban areas.

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